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Modeling of EV charging circuit by integrating renewable energy sources Solar, Wind with Grid

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ABSTRACT

This paper presents a comprehensive framework for optimizing electric vehicle (EV) charging systems through the integration of solar wind and an advanced grid system. Central to this framework is the utilization of an Artificial Neural Network (ANN) controller, which dynamically adjusts energy extraction from renewable sources by employing the Perturb and Observe (P&O) Maximum Power Point Tracking (MPPT) algorithm. The system operates across four key modes: Firstly, in the Grid-to-Vehicle (G2V) mode, EV batteries are efficiently charged from the conventional power grid, ensuring optimal energy delivery to meet evolving demand patterns. Secondly, the Vehicle-to-Grid (V2G) mode enables the controlled discharge of surplus energy from EV batteries back to the grid, contributing to grid stability and facilitating bidirectional energy flow. Thirdly, the Renewable-to-Grid (R2G) mode directs energy generated by solar photovoltaic (PV) panels into the grid, promoting renewable energy integration and reducing reliance on fossil fuels. Lastly, the Renewable-to-Vehicle (R2V) mode prioritizes the utilization of solar energy to directly charge EV batteries, minimizing grid stress during peak demand periods. Through comprehensive simulations encompassing various environmental conditions and grid operation scenarios, the proposed framework's effectiveness is rigorously evaluated, considering metrics such as energy efficiency, grid stability, and economic viability. This paper proposes underscores the potential of integrating solar wind, ANN control, and advanced grid systems to optimize EV charging infrastructure, drive renewable energy adoption, and enhance the overall sustainability and resilience of modern energy grids.

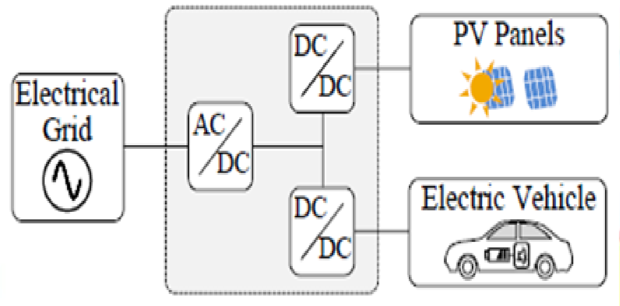
KEYWORDS: Electric Vehicle, Integrated Topology, Power Converters, solar PV, wind, Smart Grid

1.INTRODUCTION

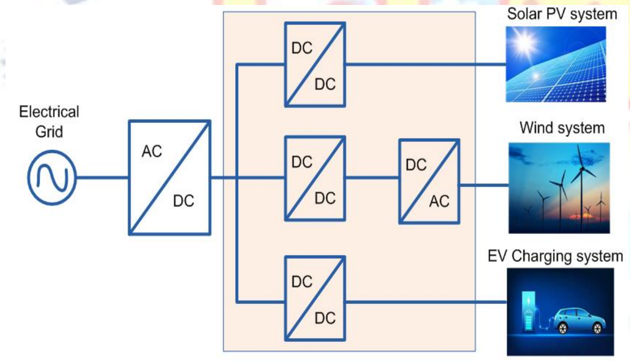
The increasing popularity of electric vehicles (EVs) is a significant development in combating climate change and environmental problems caused by fossil fuel-powered vehicle [1-2]. However, new issues arise due to the broad acceptance of EVs, particularly in optimization of charging infrastructure to satisfy rising energy needs with minimal environmental impact [3-4]. This study proposes a framework that integrates solar wind energy with new grid technology to transform EV charging facilities [5-6]. The proposed architecture has four modes: Grid-to-Vehicle (G2V) mode, Vehicle-to-Grid (V2G), Renewable-to-Grid (R2G), and

Renewable-to-Vehicle (R2V) [7]. The proposed framework uses an Artificial Neural Network Controller (ANN) controller to dynamically govern energy extraction from renewable sources. The controller optimizes power production in response to varying environmental conditions and energy demand, ensuring optimal utilization of solar wind energy [8]. The proposed architecture has four modes: Grid-to-Vehicle (G2V) mode, which allows for smooth energy supply to meet changing demand patterns; Vehicle-to-Grid (V2G) mode, which controls the discharge of excess energy from batteries and sends it back to the grid; and Renewable-to-Vehicle (R2V) mode, which promotes sustainable energy habits and reduces grid stress during peak demand hours [9]. Extensive simulations are conducted under various weather and grid operating situations to verify the framework's effectiveness. Performance parameters such as energy efficiency, grid stability, and economic practicability are assessed to evaluate its capacity to optimize EV charging infrastructure [10]. The adoption of this novel framework could accelerate the arrival of a more environmentally friendly and sustainable transport ecosystem, paving the way for more efficient use of energy in transport [11]. The usage of electric mobility, including EVs, hybrid EVs, fuel cell vehicle, and electric bicycles, contributes significantly to improving the transportation sector's sustainability and efficiency [12]. However, to avoid power quality issues, optimize its interaction with other electrical appliances, and make the most of their usage in new paradigms like microgrids, smart grids, and smart homes, it is necessary to control the massive introduction of EVs into the electrical grid [13]. Future smart grids face additional possibilities and problems due to the entry of EVs into the electrical grid. Advancements in microgeneration have opened up new possibilities for integrating EVs with renewable energy sources, including energy management strategies, economic dispatch models, smart charging strategies, and cost-minimization strategies for charging stations. Incorporating energy storage devices is also crucial for smart grid energy management, taking into account electric vehicle operations, renewable power sources, and energy storage systems [14]. Control algorithms have been developed to integrate renewable energy sources and electric vehicles (EVs) into power grids, optimizing various aspects of the integration process. These algorithms focus on grid-distributed renewable energy sources and extensive use of electric vehicles [15]. However, conventional architectures often use separate pieces of equipment, such as an ac-dc converter and two dc-dc converters, which is essential for charging EV batteries directly from renewable sources. This work aims to address this disadvantage by presenting the experimental validation of a single-phase off-board multiport integrated topology (MPIT) for residential use [16]. The goal is to connect renewable energy sources and EVs to the power grid. The proposed topology interfaces with the electrical grid, making it a significant improvement over the multi-port topology described in previous studies [17]. The proposed topology has the potential to have the EV work in bidirectional mode, meaning it can charge its batteries from either the grid or the PV panels, or send energy back to the grid. However, none of these studies take into account power quality concerns (power factor and total harmonic distortion of the grid current) on the electrical grid side [18]. This is a drawback but also shows how relevant the experimental investigation suggested in this article is. In terms of projected operational efficiency and implementation cost, the suggested topology exhibits a total cost that is 33.5% cheaper and a maximum estimated efficiency that is 8.8% higher. The network architecture that includes the MPIT, EV, PV panels, and the power grid includes four ways to accomplish this interconnection: (1) charging EV batteries directly from the grid, (2) sending part of the energy stored in the EV batteries back to the grid, (3) sending the energy produced by the PV panels to the grid, and (4) directly charging the EV batteries using

renewable-to-vehicle (R2V) operation mode. The planned MPIT aims to lessen the environmental impact while increasing efficiency and self-sufficiency in energy use. The suggested topology substantially improves upon state-of-the-art topologies by introducing electric vehicle (EV) battery chargers and renewable energy sources that connect to the grid via a single ac-dc converter; potential for R2V operating mode, a direct dc-to-dc link; an ac-dc converter and two dc-dc converters connected over a single dc-link; and verification by experimentation at the home level using the MPIT in G2V, V2G, R2G, and R2V states of operation as shown in fig.2.



(a)



(b)

Fig. 1. Interface between an EV and PV panels with the electrical grid: (a) Classical topology; (b) Proposed topology.

These modes were created to be ready for future smart grid adoption. Rearranging these modes may provide new combinations of action. With one electric vehicle (EV) and a network of solar panels and wind turbines, the suggested system aims to lessen the environmental impact of individual homes while simultaneously enhancing energy efficiency and self-sufficiency.

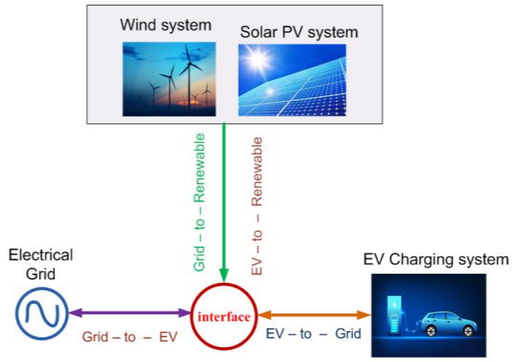


Fig. 2. Proposed hybrid system used to interface electric vehicles (EVs) and renewables from photovoltaics (PV) and wind system.

With the help of a single AC-DC converter, renewable energy sources and electric vehicle battery chargers may be linked to the power grid. In the event that the power grid goes down, the electric vehicle's battery may still be charged directly from the solar panels or wind turbines. Also, the AC-DC converter and the two DC-DC converters are linked by a single DC-link in the proposed architecture. All three converters are designed to operate with a unitary power factor and sinusoidal grid current [19, 20]. In the long run, the technology helps promote sustainability and lessens reliance on the traditional power grid infrastructure by accurately charging the electric vehicle's battery and guaranteeing the optimal integration of renewable energy sources. For eco-conscious households looking to implement renewable energy technologies, the system offers a one-stop solution. This state-of-the-art technology optimises energy flow via the use of a unified power factor, which in turn reduces vehiclebon emissions and ensures a steady supply of electricity even in the event that the traditional grid goes down. By providing a dependable and eco-friendly energy solution, this cutting-edge design helps homeowners lessen their impact on the environment. The system's efficiency and flexibility are enhanced by integrating Artificial Neural Networks (ANNs). In order to maximise the production and use of energy, ANNs optimise the MPPT algorithm, which is used to govern the extraction of maximum power from renewable energy sources. This integration provides a more sustainable and affordable energy option while reducing property owners' dependence on conventional sources. Additional energy savings may be achieved via the use of ANNs by predicting energy consumption and adjusting output appropriately. The

ANN controller optimises energy usage and reduces expenses for electric vehicle charging procedures, which in turn improves the environment and provides consumers long-term financial advantages. Effective energy management and the use of renewable energy sources are both supported by the system.

II. System Configuration

The modeling of an electric vehicle (EV) charging circuit integrated with renewable energy sources like solar and wind, along with the grid, aims to optimize energy utilization and ensure grid stability. The system comprises key components interconnected to facilitate efficient energy flow. Renewable energy sources like solar photovoltaic panels and wind turbines are integrated into the system to harness clean energy from the environment. These sources feed energy into a power conditioning unit, which converts DC output into AC power compatible with the grid and EV charging infrastructure. The grid serves as a supplementary energy source and means of energy exchange, providing backup power when renewable sources are insufficient or unavailable. It also enables bidirectional energy flow, allowing excess energy generated by renewables or stored in EV batteries to be fed back into the grid. The EV charging infrastructure consists of charging stations equipped with bidirectional chargers capable of charging EV batteries from the grid and discharging surplus energy back to the grid. Intelligent control systems, such as Artificial Neural Network (ANN) controllers, optimize energy flow, manage charging schedules, and balance energy demand in real-time. This holistic approach to sustainable energy management contributes to the devehicleburization of transportation while promoting energy efficiency and grid stability.

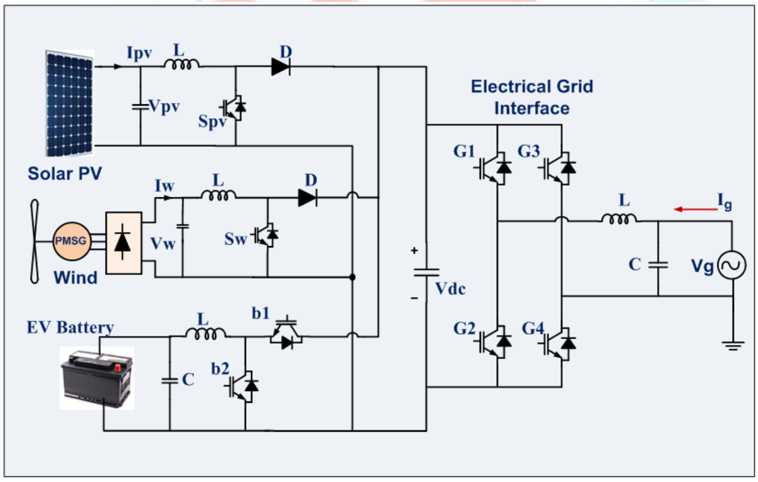


Fig. 3. Circuit of the proposed multi-port integrated topology (MPIT) used to interface EVs and renewable with the electrical grid.

III. Modelling and Design of multi-port integrated topology (MPIT)

A. Solar operation

Using the Perturb and Observe (P&O) Maximum Power Point Tracking (MPPT) algorithm, a DC-DC boost converter that runs on solar power may charge batteries or run more loads by maximising the amount of solar energy that is generated. In order for the converter to work, it needs certain components like a diode, a capacitor, an inductor, and a switch—typically a MOSFET or an IGBT—. Following the solar panel's maximum power point (MPP), when power generation peaks (as shown in fig.4), the P&O MPPT algorithm continuously modifies the operating point of the panel. The greatest quantity of power that can be extracted from the solar panel is ensured by repeating this method. Combining the P&O MPPT algorithm with the DC-DC boost converter allows for efficient energy conversion and utilisation in solar-based systems. Because it can maintain operation close to its maximum power output, the system is more efficient and performs better overall. To do this, the converter's operating settings are changed in real time to reflect the current situation.

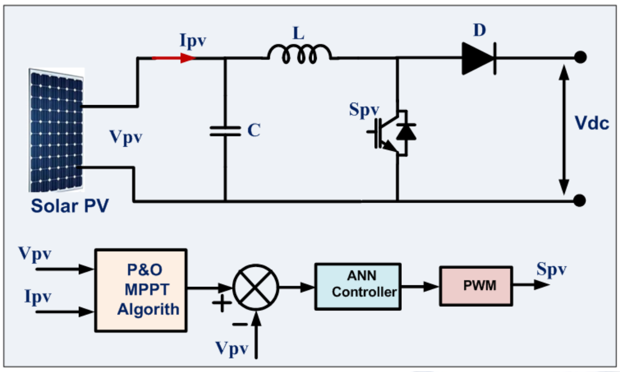


Fig.4 solar MPPT DC-DC unidirectional converter

B. Wind Operation

By converting alternating current (AC) to direct current (DC), a Permanent Magnet Synchronous Generator (PMSG) may transform wind energy into usable electricity by spinning turbine blades. An alternating current (AC) output is converted to a pulsing direct current (DC) voltage using a rectifier circuit. The use of diodes grouped in a bridge design accomplishes this by limiting the current flow to just one direction. Nevertheless, since rectified DC power is pulsing, it still includes ripples. By storing and discharging electrical energy in capacitors, ripples may be reduced and a more stable DC output can be produced. When charging batteries or powering loads that need a greater voltage, it may be necessary to increase the DC voltage. An inductor stores energy in a DC-to-DC boost converter, which transfers it to the load in a different phase. In order to maximise energy extraction from the wind, the Perturb and Observe (P&O) Maximum output Point Tracking (MPPT) algorithm keeps the wind turbine running at its peak output. By optimising the turbine's operational settings in response to current wind speed, turbine output, and other pertinent data, the maximum power point tracking (MPPT) algorithm maximises power production while simultaneously improving efficiency and performance. To top it all off, the MPPT algorithm keeps an eye on the weather and makes adjustments to the turbine's operating position in response to new information, so it can keep up with different wind speeds. The maximum power point tracking (MPPT) algorithm aids in optimising energy output and system efficiency by making real-time adjustments to the turbine's settings. Regardless of changes in wind conditions, the turbine can continue to function at its full efficiency because to its adaptive control system. In the end, the MPPT algorithm makes the wind turbine system far more efficient and productive.

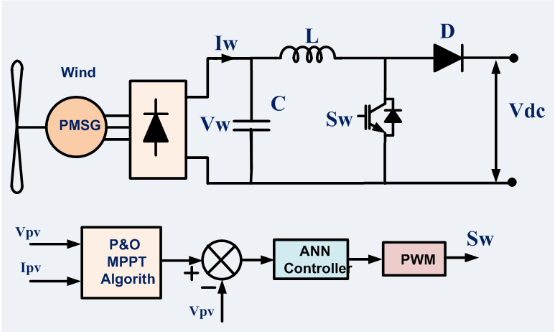


Fig.5 wind power generation with MPPT DC-DC unidirectional converter

C. AC - DC Bidirectional Converter

Figure 6 shows the intricate AC-DC bidirectional converter, which is a crucial component of modern power systems. It is a crucial part because it allows for efficient and versatile control of power flow between alternating current and direct current grids. When functioning in the AC to DC mode, the converter also rectifies voltage. It does a good job of converting mains or other AC sources into DC power. Adjusting the voltage requires complex control algorithms and semiconductors like diodes, thyristors, or IGBTs. These devices smooth down the AC current's waveform and convert it to DC. In addition to rectifying, bidirectional converters may shift into reverse mode and transform DC power into AC power. Applications like grid-tied renewable energy systems need this inversion, or conversion, from direct current to alternating current. To feed DC energy into the grid or power AC loads, these systems convert DC power from sources like batteries or solar panels into AC power. Bidirectional converters maximise system efficiency by allowing efficient conversion with minimum losses via clever regulation of semiconductor device switching. The ability to transfer energy between the AC and DC grids is another useful feature of bidirectional converters, which allows them to adapt to different situations. Applications like energy storage systems greatly benefit from this bidirectional capacity since it enables energy to be stored in batteries during periods of low demand and then either turned into alternating current power or discharged back into the grid during periods of high demand. By allowing power to flow in both ways, these

converters help stabilise the grid, integrate renewable energy sources, and make the system more resilient overall. In most modern power systems, AC-DC bidirectional converters play a crucial role. Their use allows for the seamless integration of AC and DC sources, maximising efficiency, flexibility, and reliability all at once. Their versatility makes them indispensable in many different contexts, including electric vehicles, renewable energy systems, grid-connected power systems, and industrial power supply, among many others. This positions them as a key player in the race to build long-term, environmentally friendly energy infrastructure.

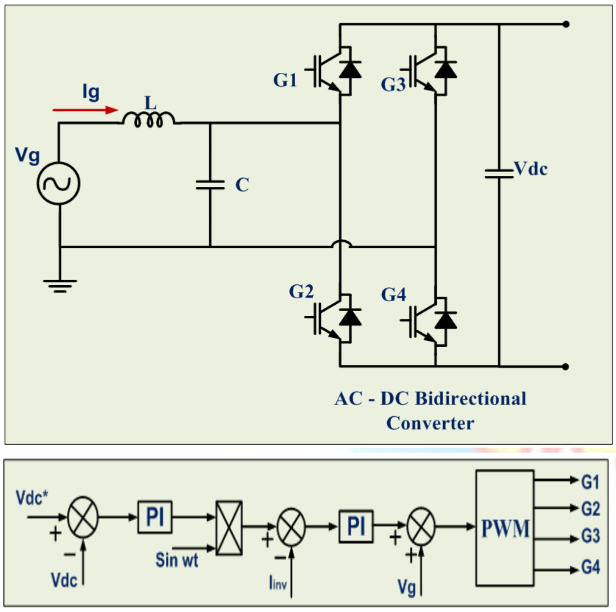


Fig.6 configuration of a AC-DC Bidirectional Converter control

D. Rectification operation

a. Rectification Efficiency: An efficient diode rectifier will have a DC output power that is proportional to the AC input power, with the following losses taken into account:

$$\frac{P_{DC}\ output}{P_{AC}\ input} \times 100\%$$

b. Peak Voltage (V_{Peak}): The rectified output waveform's peak voltage may be determined by:

$$V_{Peak} = V_{rms} \times \sqrt{2}$$

Where V_{rms} is the root mean square (RMS) voltage of the AC input waveform.

c. Peak-to-Peak Voltage (V_{PP}): The rectified output waveform has a voltage that is twice as high as its peak:

$$V_{PP} = 2 \times V_{Peak}$$

d. Average DC Voltage (V_{avg}): The rectified output waveform's average DC voltage is about equal to:

$$V_{avg} = \frac{V_{Peak}}{\pi}$$

e. Ripple Voltage (V_{ripple}): As a measure of the fluctuation in the DC output voltage, the ripple voltage may be determined by:

$$V_{ripple} = V_{Peak} - V_{avg}$$

f. Ripple Factor: The following is the formula for the ripple factor, which measures the ripple voltage relative to the average DC voltage:

$$Ripple\ factor = \frac{V_{ripple}}{V_{avg}} \times 100\%$$

g. Peak Current (I_{Peak}): The formula for determining the maximum current passing through the load resistance is:

$$I_{Peak} = \frac{V_{Peak}}{R}$$

Where R is the load resistance.

E. Inversion operation

Inversion Efficiency (η): An inverter's inversion efficiency indicates how well it changes direct current (DC) into alternating current (AC). In order to determine it, one must take into account losses and compare the AC output power to the DC input power.

Inversion Efficiency (η)= $\frac{P_{AC\ output}}{P_{DC}\ \text{input}}$×100%

Where P_{AC} output is the power delivered to the load by the inverter in the form of AC voltage and current, and P_{DC} input is the power supplied to the inverter from the DC source.

a. AC Power Output (P_{AC}): Multiplying the root-mean-square (RMS) voltage and current of the

AC waveform output by the inverter yields the AC power output:

$$P_{AC} = V_{rms} \times I_{rms}$$

b. DC Power Input (P_{AC}): The inverter receives its DC power from the voltage and current multiplied by the DC input:

$$P_{DC} = V_{DC} \times I_{DC}$$

c. Power Losses (P_{loss}): Various inverter power losses, including as switching losses and conduction losses, may be determined by subtracting the DC input power from the AC output power:

$$P_{loss} = P_{DC} - P_{AC}$$

d. Efficiency Losses:

The inverter's efficiency losses, which are the discrepancy between the ideal and real inversion efficiencies, may be expressed as:
Efficiency Losses=100%$-\eta$

IV. DC-DC Bidirectional Converter

Figure 7 shows how the bidirectional DC-DC converter improves grid efficiency and reliability in vehicle-to-grid operations by drawing on the energy stored in electric vehicle batteries to help stabilise the grid during times of high demand or crises. While delivering useful grid services, the converter's clever control algorithms actively regulate bidirectional power flow, keeping EV batteries charged within defined limits. In order to optimise grid performance and decrease dependence on conventional power production based on fossil fuels, these services may include frequency management, voltage assistance, and peak shaving, among others. Furthermore, unique grid services like vehicle-to-home (V2H) and vehicle-to-building (V2B) capabilities are made possible by bidirectional converters. This means that EVs can power houses or buildings even when the power goes out or when the energy rates are too high. These solutions encourage energy resilience at the community level by tapping into the energy stored in EV batteries, which provides a stable backup power supply. A key component of grid-to-vehicle (G2V) operations, bidirectional converters allow for efficient grid-based EV charging. These converters provide secure, rapid, and loss-free charging of electric vehicle batteries by transforming grid AC power to DC power that is more appropriate for charging EV batteries. Smart charging techniques including load balancing, demand response, and time-of-use charging are made possible by bidirectional converters, which enable bidirectional communication between the grid and the EV. These features optimise charging efficiency, minimise infrastructure costs for electric vehicle charging, and assist alleviate grid congestion. When it comes to building a more efficient, reliable, and environmentally friendly energy system, bidirectional DC-DC converters play a crucial role. In the future, when transportation and energy systems are intimately linked, there will be more efficiency, dependability, and environmental sustainability. These converters make this possible by easily connecting EVs to the grid and making full use of vehicle-to-grid capabilities. During buck mode, when the battery is charged, and boost mode, when power is sent to the vehicle's systems, a bidirectional DC-DC converter efficiently transfers energy between the EV battery and external power sources, such as charging stations.

Mode 1: Battery Charging (Buck Mode)

a. Switch S1 and Diode D2 Operation: With diode D2 biassed forward and switch S1 closed, this mode is activated. The electric vehicle's battery receives electricity from an external source (such a charging station) via the closed switch, and diode D2 guarantees that the current can only travel in one direction.

b. Buck Mode Operation: The converter is in buck mode when it functions, which means it reduces the voltage from the outside source so it can match the lower voltage of the electric vehicle's battery. To charge the battery efficiently, it is essential to make sure it gets the right voltage.

c. Charging the Battery: The electric vehicle's battery is charged effectively when electricity is transferred from an external source to it. In order to accomplish the required voltage conversion ratio while operating in buck mode, the switch's duty cycle must be controlled. Some of the most important buck mode formulae are:

- Voltage Conversion Ratio (Duty Cycle, D): D =

$\frac{V_{out}}{V_{in}}$

- Inductor Current (I_L): $V_{out} = \frac{V_{in}\times(1-D)}{D\times(1-D)\times I_L}$
- Output Power (Pout): Pout = $V_{out} \times I_L$
- Efficiency (η): η = $\frac{P_{out}}{P_{in}} \times 100\%$

Mode 2: Battery Discharging for Power Delivery (Boost Mode)

a. Switch S2 and Diode D1 Operation: With diode D1 biassed forward and switch S2 closed, this mode is activated. Diode D1 guarantees one-way current flow, and the closed switch permits current to flow from the EV battery to the load, such as electric motors.

b. Boost Mode Operation: When the converter is in boost mode, it raises the voltage from the electric vehicle's battery to meet the voltage requirements of the load. Even if the load voltage is greater than the battery voltage, this is critical to ensure that the vehicle's systems get enough power.

c. Power Delivery: The electric vehicle may move and function as needed since energy is transferred from the battery to the load. In order to obtain the necessary voltage conversion ratio when operating in boost mode, the duty cycle of the switch is controlled. Here are the main formulae for boost mode:

- Voltage Conversion Ratio (Duty Cycle, D): D = $\frac{1}{1-\left(\frac{V_{out}}{V_{in}}\right)}$
- Inductor Current (I_L): Vout = $\frac{V_{in}}{(1-D)\times I_L}$
- Output Power (Pout): P_{out} = $V_{out} \times I_L$
- Efficiency (η): η = $\frac{P_{out}}{P_{in}} \times 100\%$

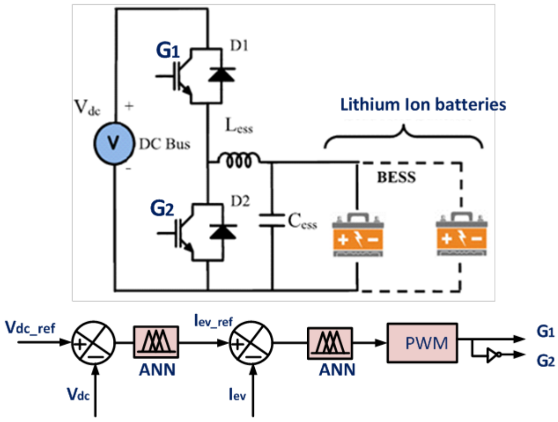


FIGURE 7. Bidirectional DC-DC converter configuration for Electric Vehicle Battery charging.

V. DC-DC UNIDIRECTIONAL CONVERTER

Power converters like the DC-DC unidirectional boost converter (fig.8) increase the input voltage above the output voltage. Energy is transferred in a unidirectional fashion from the input source to the output load, often from a lower-voltage source to a higher-voltage load. The basic layout of a boost converter consists of an inductor, a switch (often a MOSFET), a diode, and an output capacitor. The inductor allows current to flow while the switch is left closed, causing the magnetic field to store energy. When the switch is opened, the inductor can tolerate fluctuations in current flow, which causes a voltage to be inducted across itself on the other side of the switch. That voltage, when added to the input voltage, raises the voltage across the output capacitor. A current may flow from the inductor to the output capacitor and load because the diode is forward-biased. The output voltage of the boost converter may be fine-tuned by adjusting the duty cycle of the switch. Unidirectional boost converters find widespread usage in a variety of applications, including power supply, LED drivers, and renewable energy systems. In order to satisfy the load requirements, this kind of converter is usually used when the input voltage has to be increased.

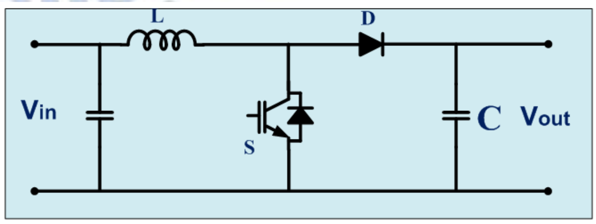


Fig.8 DC-DC unidirectional boost converter

a. Output Voltage (V_{out}): The output voltage of a

boost converter can be calculated using the following formula:

$$V_{out} = \frac{V_{in}}{1-D}$$

Where Vin is the input voltage and D is the duty cycle of the converter.

b. Input Current (I_{in}): The input current of the boost converter can be calculated as:

$$I_{in} = \frac{I_{out}}{1-D}$$

Where I_{out} is the output current of the converter.

c. Output Current (I_{out}): The output current of the boost converter can be approximated as:

$$I_{out} = \frac{P_{out}}{V_{out}}$$

Where P_{out} is the output power.

d. Efficiency (η): The efficiency of the boost converter can be calculated as the ratio of output power to input power:

$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

Where Pin is the input power.

e. Inductor Current Ripple (ΔI_L): The peak-to-peak ripple current flowing through the inductor can be approximated as:

$$\Delta I_L = \frac{V_{in} \times D \times T_{on}}{L}$$

where Ton is the on-time of the switching device and L is the inductance.

f. Output Voltage Ripple (ΔV_{out}): The peak-to-peak ripple voltage at the output can be approximated as:

$$\Delta V_{out} = \frac{V_{in} \times D \times T_{on}}{C}$$

Where C is the output capacitance.

VI. Neural Network Model

For a single-input, single-output (SISO) control system, let:

- x(t) be the input at time t,
- u(t) be the control output at time t,
- y(t) be the actual output of the system at time t.

The neural network consists of an input layer, a hidden layer, and an output layer. Let:

- wij be the weight connecting the i-th node in the input layer to the j-th node in the hidden layer,
- vj be the bias of the j-th node in the hidden layer,
- zj(t) be the output of the j-th node in the hidden layer.

Similarly, let:

- bk be the bias of the k-th node in the output layer,
- wjk be the weight connecting the j-th node in the hidden layer to the k-th node in the output layer,
- yk(t) be the output of the k-th node in the output layer.

a. Forward Pass Equations:

The forward pass of the neural network can be expressed as follows:

Hidden Layer Output (zj(t)):

$$z_j(t) = \sigma\left(\Sigma_i w_{ij} \cdot x(t) + v_j\right)$$

Where σ is the activation function (e.g., sigmoid, tanh, ReLU).

Output Layer Output (yk(t)):

$$y_k(t) = \Sigma_j w_{jk} \cdot z_j(t) + b_k$$

b. Training and Backpropagation:

During training, the weights and biases are adjusted to minimize a chosen loss function L. One common loss function for regression problems is the mean squared error:

$$L = \frac{1}{2N}\sum_{t=1}^{N}\left(y(t) - u(t)\right)^2$$

The backpropagation algorithm is used to compute the gradients of the loss function with respect to the weights and biases. The weights and biases are then updated using gradient descent or other optimization algorithms. The weight update rule for the hidden layer weights wij is given by:

$$\Delta w_{ij} = -\eta \frac{\partial L}{\partial w_{ij}}$$

Where η is the learning rate.

The chain rule is applied to compute the partial derivatives in the backpropagation algorithm.

This is a simplified representation, and actual implementations may involve additional considerations, such as regularization techniques, different activation functions, and optimization strategies. The specific choice of these components depends on the characteristics of the control problem and the desired properties of the control algorithm [21-22].

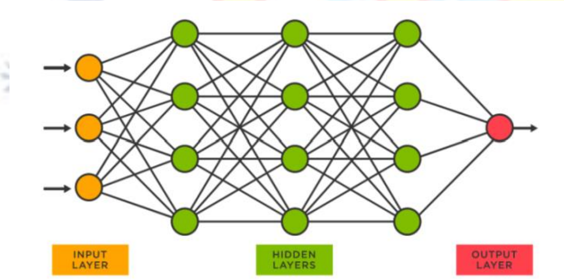
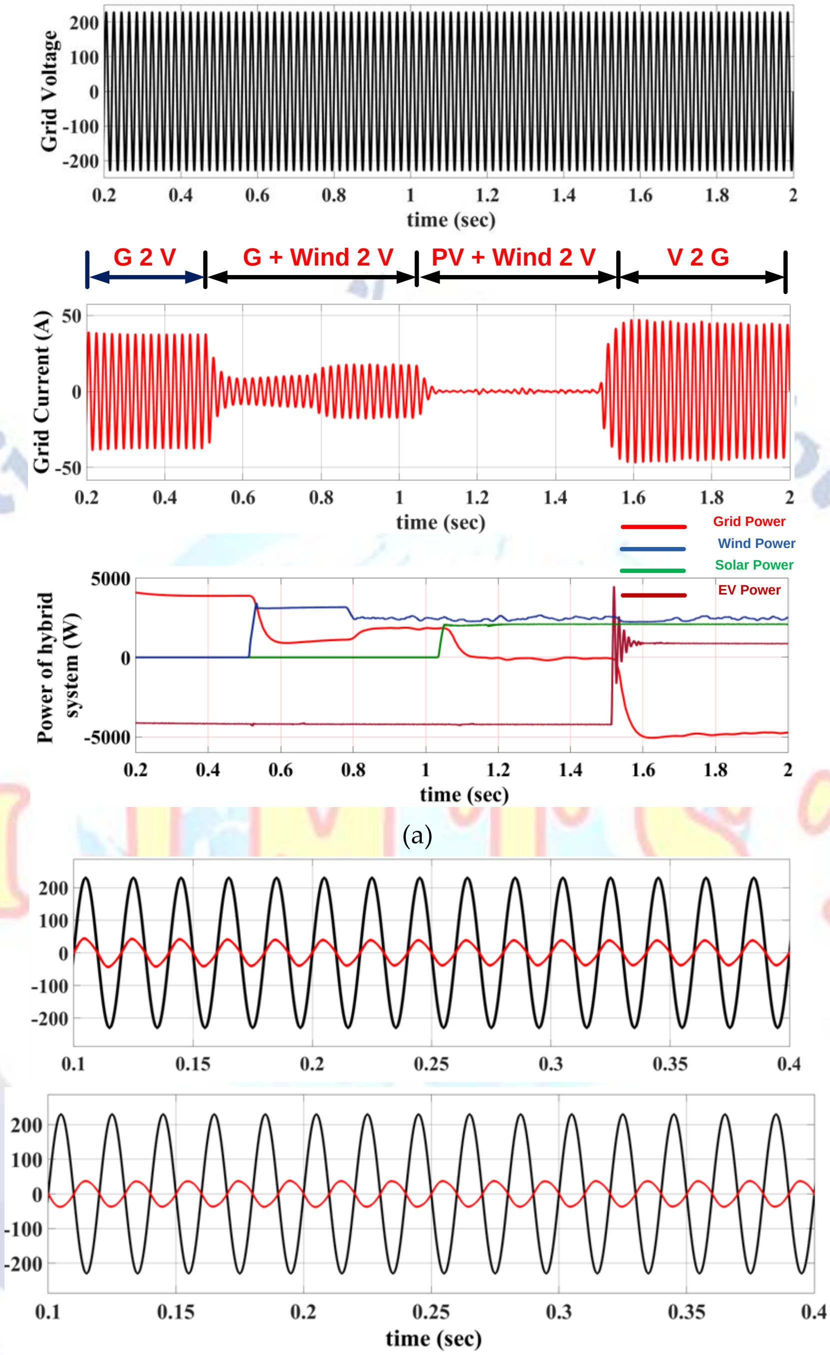


Fig. 9 Design of a backpropagation network to provide a standard reference signal.

VII. Results and Discussion

This hybrid system may be linked to a microgrid, wind, and solar electricity to make it easier to charge electric vehicles. Utilising smart technology, the system provides a green solution for transportation and renewable energy by maximising energy storage and utilisation. In addition, it has the option to sell any excess energy back to the grid, which is a fantastic method to save expenses and boost productivity. Electric vehicle charging networks powered by renewable energy sources will contribute to a cleaner, more sustainable world. This will reduce greenhouse gas emissions and the need for fossil fuels. Real-time monitoring and control are made possible by smart technology integration, which ensures effective energy management while optimising the benefits of renewable energy sources. Figure 10(a) illustrates that during the G 2 V phase of operation, which lasts from 0.2 to 0.5 seconds, electric automobiles charged with grid-supplied solar and wind energy did not generate any power. This highlights the need of a consistent grid power supply to ensure that electric vehicle charging is always possible. Energy storage technologies should be implemented in order to lessen the effects of these fluctuations and increase the dependability of renewable energy sources for transportation. Reduced electric vehicle charging might result in a potential power outage as solar PV systems can operate in G2V and PV2V modes for 0.5 to 1.2 seconds of grid supply. Integrating energy storage devices, such as batteries, which can store and use the excess energy generated during peak hours, may result in a more dependable power source for EVs. Storage devices may be included to maximise the use of renewable energy sources and enhance grid resilience for transportation needs. Since they can get all of their power from renewable energy sources like solar and wind, electric vehicle never require any electricity from the grid. Usually, wind power generation starts 1.2 to 1.5 seconds after solar power generation. This mode is PV2V+W2V. As a result, there is a reduced demand for traditional fossil fuels, and the energy source for electric vehicles is more reliable and sustainable. Moreover, solar and wind-powered electric vehicle charging systems might contribute to the mitigation of greenhouse gas emissions and the battle against climate change. The vehicle enters the back-to-grid (V 2 G) mode of operation when renewable energy isn't available for 1.5–2 seconds. This mode allows the electric vehicle to return excess energy to the grid in the event that renewable energy sources aren't available, which promotes more efficient use of resources. V2G technology enhances the overall sustainability and flexibility of electric vehicle charging systems. With the help of this cutting-edge technology, electric vehicle may now use clean energy and help keep the grid stable overall at times of high demand. V2G systems assist balance supply and demand, which improves the efficiency and dependability of renewable energy integration by permitting bidirectional energy flow.



(b)

Fig.10 different modes of hybrid system power flow conditions for bidirectional grid to vehicle with renewable energy sources

As shown in Figure 10(b), it is not feasible to charge electric automobiles using renewable energy sources. The grid will then provide the electricity, and since the grid's voltage and current flow in unison, the electric vehicle will be charged effectively. When renewable energy sources are seamlessly integrated into the grid, overall energy consumption is optimised and reliance on non-renewable resources is decreased. Vehicle that are able to operate vehicle-to-grid may also feed the grid and allow the grid's voltage and current to flow in opposing directions, allowing energy to flow in both ways. This state-of-the-art technology allows for a more flexible and ecologically friendly energy supply by using electric automobiles as mobile energy storage units.

VIII. Conclusion

In this conclusion a framework that integrates wind, solar, and electric vehicle (EV) connections into the

electrical grid using an Artificial Neural Network (ANN) control-based topology. This approach enables efficient utilization of renewable energy by adjusting extraction based on environmental conditions and demand. The framework offers flexibility in meeting evolving energy needs while promoting grid stability and renewable energy integration. Simulations validate the effectiveness of the framework, demonstrating its capacity to optimize EV charging infrastructure, reduce reliance on fossil fuels, and enhance the sustainability and resilience of modern energy grids. The integration of wind, solar, and EV connections through an ANN control-based topology is a significant step forward in addressing climate change, energy security, and environmental sustainability challenges. By promoting renewable energy adoption, optimizing charging processes, and facilitating grid-balancing services, the proposed framework contributes to building a more sustainable and resilient energy ecosystem for future generations.

Conflict of interest statement

Authors declare that they do not have any conflict of interest

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